Acta Orthop Scand 56, 416–418

Bone atrophy after plate fixation

Computed tomography of femoral shaft fractures

Twelve patients with previous femoral shaft fracture treated by rigid plate fixation were examined by computed tomography (CT) scanning 1 or 2 days after plate removal. In the previously plated segment an average reduction in cortical density of 11 per cent was found, and the reduction was most pronounced in the cortex directly beneath the plate. No reduction in cortical thickness of the plated bone occurred. Proximal and distal to the site of the plate, and in the ipsilateral tibial shaft, a slight reduction in cortical density and thickness averaging 2–3 per cent was found.

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Rigid metal plate fixation protects the bone from normal stress, causing considerable bone atrophy and reduced strength, clearly documented in animals (Uhthoff & Dubuc 1971, Tonino et al. 1976, Låftman et al. 1980). However, in the human tibia DC-plates of stainless steel had less pronounced effects (Terjesen et al. 1984). We have studied this problem in patients with femoral shaft fracture.

Patients and methods

Twelve patients with previous plate osteosynthesis for femoral shaft fracture were examined. There were four females and eight males with median age 25 (17–65) years. One femoral DC-plate of stainless steel (cross-section 16 × 5 mm) fixed with 7–18 screws had been applied on the lateral aspect of the femur in 11 cases. In one case two plates had been used. The median interval from application to removal was 2 (1–14) years. All the fractures were completely healed at the time of plate removal.

Scanning procedure

The first four patients were examined by the EMI 5005 scanner and the remaining eight cases by the General Electric 9800 scanner, a third-generation, high-resolution whole body scanner. A slice thickness of 5 mm and a pixel size of 1 × 1 mm were chosen, and the exposure factors were 120 kVp, 140 mA and 4 s.

The CT scanning was done 1 or 2 days after plate removal. The patients were lying in the supine position with the legs parallel. The correct sections to be scanned were obtained by the initial scout view (Figure 1). Scanning was performed at cross-sections of the bone halfway between two screw holes but outside the fracture area, and at the corresponding levels of the contralateral control bones (Figure 2). The usual level was between holes number two and three from the proximal or distal end of the plate. In most of the patients two or three scans at various levels were carried out, and the average values were used for the calculations. Cross-sectional CT scans were also performed 3–5 cm proximal or distal to the end of the plate, and at the mid-diaphyseal level of both tibiae.

The cortical density and thickness were calculated from the CT scans, and the values for the plated side expressed as the percentages of the values for the control side. The cross-section of the bone was divided into four quadrants (lateral, medial, posterior and anterior), and the cortical density separately measured for each quadrant. The cortical thickness was difficult to measure accurately, because in many cases it varied considerably within the same quadrant. In these cases the average value was used.

Statistics

The Wilcoxon signed rank test for paired samples (two-tailed test) was used to calculate the statistical differences between the previously plated bones and the control bones. Differences were considered significant at P-values below 0.05.

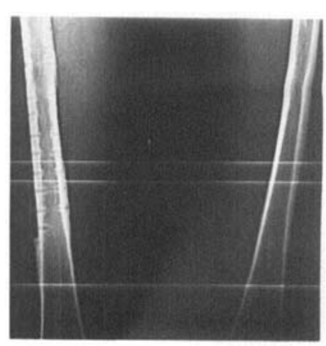

Figure 1. Initial scout view of the previously plated and control femora Scanning was performed at two levels between screw holes, and distal to the site of the plate, as indicated by the lines.

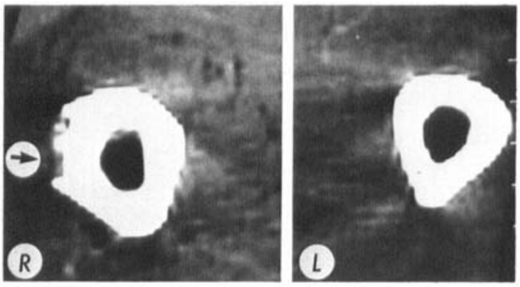

Figure 2. CT scan of the previously plated femur (R) and the control bone (L). The site of the plate on the lateral aspect is shown (→).

Table 2. Cortical density directly beneath the plate, related to time interval between plate application and plate removal, and to the age of the patient. The values are given as the median (range) percentages of the values for the contralateral bones

		n	Density
Time interval, (yr)	1– 2	4	85(77–87)
	2– 3	4	81(72–94)
	3–14	4	87(76–95)
Patient age, (yr)	17–30	7	87(77–94)
	30–40	2	85(74–95)
	60–65	3	76(72–85)

Results

The cortical density was reduced in all four quadrants of the previously plated bone segment ($P<0.001$), on average by 11 per cent (Table 1). The reduction was most pronounced in the lateral quadrant, that is in the cortex directly beneath the plate. The cortical density beneath the plate did not decrease with an increasing time interval between plating and plate removal (Table 2). The cortical density of the plated bone in patients above 60 years of age appeared decreased, but the number was too small for meaningful statistics.

In the femoral diaphysis, proximal and distal to the site of the plate, the density was slightly reduced in the anterior quadrant ($P=0.024$), while this was not the case in the other quadrants (Table 1). The average reduction of the four quadrants was only 2 per cent.

The cortical thickness of the plated segment was increased in the medial quadrant ($P=0.004$), that is opposite the site of the plate, while no differences occurred in the other quadrants. In the bone proximal and distal to the site of the plate there was a reduction in thickness of the lateral quadrant ($P=0.024$), but no differences in the other quadrants were found.

In the ipsilateral tibial shaft a slight reduction in cortical density and thickness occurred, averaging 2.5 and 2 per cent, respectively. However, the cortical density was significantly reduced only in the anterior quadrant ($P=0.005$).

Table 1. Cortical density and thickness of the previously plated femora, given as the median (range) percentages of the corresponding values for the contralateral control bones

	Lateral	Medial	Posterior	Anterior
Density				
A	85(72–95)	92(87–99)	87(55–94)	90(63–99)
B	102(88–110)	99(89–105)	97(61–109)	95(63–106)
Thickness				
A	97(78–160)	131(100–160)	106(77–122)	101(78–131)
B	91(80–105)	94(82–110)	103(70–115)	95(75–112)

A: plated bone segment. B: outside the site of the plate.

Discussion

Computed tomography scanning is an appropriate method for evaluating bone density and dimensions, since accurate and reproducible results are obtained (Lange et al. 1978, Revak 1980). A potential error might result from scanning at the level of a screw hole instead of between two screw holes. However, provided that the patient does not move his legs during the examination, the correct level is easily determined from the initial scout view.

Refior et al. (1975) found increased bone porosity in the subtrochanteric region after intertrochanteric femoral osteotomies treated by plate fixation, but the extent of the osteopenia was not quantified. These findings are in accordance with the results of our study, since a decreased cortical density, which reflects a decreased mineral content, and no decrease in cortical thickness, occurred in the previously plated segment.

The most important single factor that determines the degree of stress-protection is probably the stiffness of the plate relative to that of the bone (Tonino et al. 1976, Moyen et al. 1978). In a previous study of the stress-protection of the human tibia after plating with tibial plates of stainless steel, an average reduction in cortical density of the plated segment of 8 per cent was found (Terjesen et al. 1984). The average reduction of 11 per cent in the present study might be due to the fact that the bending stiffness of the femoral plate is more than twice that of the tibial plate. Although the elastic stiffness of the femur is greater than that of the tibia, this difference is less than the difference in stiffness of the plates. Femoral plates are usually longer, and thus fixed by more screws than tibial plates, which might also contribute to the more pronounced stress-protection in the human femur compared to that of the tibia.

The bone loss was greatest in the quadrant directly beneath the plate, which is in agreement with the findings of most animal studies (Uhthoff & Dubuc 1971, Matter et al. 1974, Akeson et al. 1976, Claes et al. 1981, Terjesen & Benum 1983). No substantial increase in stress-protection with increasing duration of plating beyond 1–2 years occurred, which corresponds well with the findings in plated tibiae (Terjesen et al. 1984). Thus, it seems that the stress-protecting effect in human long-bones reaches a stationary stage in less than 2 years. The clinical relevance of this might be that the harmful effects of not removing a rigid femoral plate are small, as far as stress-protection and osteopenia are concerned.

In most animal studies thinning of the cortex beneath the plate has been found (Akeson et al. 1976, Tonino et al. 1976, Moyen et al. 1978, Strömberg & Dalén 1978). This was not confirmed in our study, and was not observed either in the sheep radius (Baggott et al. 1981) or in the human tibia (Terjesen et al. 1984). Whether these divergent findings are due to the different test models used, or whether there are real differences among various species and bones, is not known.

In order to reduce the extent of stress-protection, it might be advisable to reduce the stiffness of the femoral plates somewhat. However, too great a reduction in stiffness is hazardous, as it increases the risk of mechanical failure of the implant.

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